

# **Development of Tools for Remote Detection and Prediction of Low-Strength Muds in Energetic Coastal Environments**

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## **LONG-TERM GOALS**

The goals of this research are to understand size-sorting during erosion and deposition and to use this understanding to develop predictive models of where and when low-strength muds will accumulate in energetic coastal environments.

## **OBJECTIVES**

1. To use our process-based parameterization of surficial seabed disaggregated inorganic grain size (DIGS) distributions to infer the extent of flocculation during deposition on energetic tidal flats.
2. To use time series of in situ suspended sediment properties, waves, and currents. to improve understanding of how turbulence, sediment concentration, and cohesion affect the size-dependent depositional flux of sediment to the seabed on energetic tidal flats.
3. To improve understanding of how sediment texture, cohesion, and sorting in the seabed affect the size-dependent erosional flux from the seabed on energetic tidal flats.

## **APPROACH**

Variability in seabed properties represents a major concern for safe and efficient travel across tidal flats. Especially problematic are “oozing mudflats” (cf. Wells, 1983, Frey et al., 1989) with high porosity and low strength. People and equipment can sink deeply into such muds, making travel difficult and potentially dangerous. The link between seabed properties and “trafficability” motivates efforts to detect low-strength muds remotely and to develop models that can predict the locations of such deposits.

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Physical properties of the seabed depend fundamentally on particle size. This dependence endows energetic coastal tidal flats with extraordinary variability in seabed properties, because these are the only environments on Earth where mud, sand, and gravel are all actively eroded, transported, and deposited. Over the course of a single tide, a spring-neap tidal cycle, a season, or a year, seabed grain size at a single location can change dramatically on an energetic flat (e.g., Choi et al., 2004).

Turbulence, sediment concentration, and cohesion are the most important factors in determining extent of flocculation. Energetic turbulence induces floc breakup, and high sediment concentration favors rapid floc formation (Milligan et al., 2007). Under some conditions, fine suspended sediment can build to such high concentrations that it dampens turbulence, leading to rapid deposition of mud on the seabed. This interaction of fine suspended sediment and turbulence is an important mechanism for retaining muds in high energy environments (Hill et al., 2007). Cohesion, or “stickiness”, affects the formation rate of flocs as well as their resistance to breakup by physical forces. The controls on cohesion are complex, but it is generally believed that exudates from plankton and bacteria are important to formation and sedimentation of flocs (Verdugo et al., 2004).

Size sorting during erosion of mixed grain size deposits accentuates abrupt transitions in seabed texture (Law et al., 2008). When muddy sands are eroded, the smallest sediment sizes are winnowed from the bed, essentially cleaning the sands. This winnowing is consistent with conventional sedimentological models that link frequent resuspension to well sorted deposits. In contrast, when sandy muds are eroded, size sorting is reduced substantially. In short, after deposition, sands, and presumably gravels, are “cleaned” by physical disturbance, but muds resist any further sorting. Even if muds are repeatedly resuspended and transported over great distances, they maintain their poorly sorted character and small mean size.

These depositional and erosional mechanisms are capable of explaining the persistence of poorly sorted muds in energetic coastal environments, yet they are not well tested. Through use of field observations, we are testing parameterizations that incorporate the processes underlying size-sorting into numerical models of fine sediment transport and seabed properties.

To examine spatial and temporal variability in tidal flat grain size, samples are being collected over a wide area at different time scales. The samples collected for DIGS analysis will be interpreted with our process-based parameterization (Curran et al., 2004; Milligan et al., 2007). The parameterization yields information on the extent of flocculation of depositing sediments, on sediment source, and on the maximum transported size, which is linked to energy. A key aspect of this seabed sampling effort is the development of techniques to collect cores in shallow water without otherwise disturbing the sediment surface by walking across it. To do this we have modified the core head from one of our slow-corers to allow us to collect cores with undisturbed sediment water interfaces from a kayak.

To evaluate the size dependent removal of sediment from the tidal flat, a Gust chamber was mounted to the top of the cores to erode the undisturbed surfaces (Law et al., 2008). By adjusting the speed of a rotating disk at the top of the chamber, the sediment surface is exposed to increasing shear stresses. The Gust device replaces water overlying the eroding core with background water collected at the site. By comparing the DIGS in the water withdrawn from above the core to the DIGS of the surficial sediment, we can establish the degree of sorting that occurs during erosion. Based on past work in the laboratory (van Ledden et al., 2004) and in the field (Law et al., 2008), we anticipate that the fraction of the bed sediment in sizes less than 4  $\mu\text{m}$  will be critical in determining how much sorting takes

place. When this fraction is less than 5-10%, finer sediments are easily sorted from coarser sediments. Sorting is minimal when the fine fraction rises higher than 10%.

To investigate depositional sorting, time series of floc size, component grain size and settling velocity will be collected with a modified version of INSSECT (Mikkelsen et al., 2004; Curran et al., 2007). In its current form it is being used as part of the ONR-funded OASIS project. With these measurements we can fully describe the size dependent depositional flux at a single height above the seabed. By combining INSSECT with the time series observations being made by University of Washington we can link depositional flux to physical forcing. To deploy INSSECT we modified the frame so that it can be constructed on site from a small boat or kayak. The frame comprises anchored legs joined by struts from which a digital floc camera (DFC), LISST, settling column and McLane water transfer system are hung. The frame was successfully deployed in September and will be used during the next sampling period.

Our effort is being integrated with others working contemporaneously. In particular we are working with Rob Wheatcroft from OSU who is collecting information of porosity, Pat Wiberg of UVA who is studying erosion rates and Bernie Boudreau of Dalhousie University who is looking at sediment strength.

## **WORK COMPLETED**

A field program to sample the surficial grain size of the Willapa Bay Tidal Flat, Washington State, and to evaluate sampling protocols was carried out in September 2008. Considerable effort was made to avoid disturbing the surface of the flat. To help navigate the flat, the channels were mapped a low tide with GPS and a common file of tracks was shared among all researchers. Surficial sediment samples were collected along several transects at high water and from a kayak during the initial flooding of the flat. The new hand held corer was successfully used to collect cores with undisturbed sediment water interfaces from both a kayak and a small boat. Erodibility, resistivity and strength measurements were made on a total of 5 cores during this evaluation period.

The modified INSSECT frame was successfully deployed with very little disturbance of tidal flat surface outside of the anchor points. To address the possible issue of high turbidity compromising our ability to measure in situ particle size, the LISST and DFC were moored for 18 h in one of the main channels.

## **RESULTS**

We have developed and tested the tools necessary to investigate size sorting of tidal flat sediments without disturbing the surface of the flats. We have mapped the tidal channels with GPS, allowing us and others to navigate the flats at all stages of the tide.

## **IMPACT/APPLICATIONS**

The study will improve our ability to model tidal flat sediment dynamics and lead to an ability to predict geotechnical properties related to trafficability.

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